NASA Magazine

winter 1994

from the administrator

We at NASA are rewriting the pages of our future. Change has been making itself felt around the agency for some months now. We are moving the culture of this proud agency toward a triad of values, based on relevance, responsibility and teamwork.

I believe NASA is well postured to continue operating at the cutting edge of science and technology. We can continue to make fundamental contributions to the store of human knowledge. We are all very proud of the NASA team effort that effected the successful Hubble repair mission during STS-61 in December.

We have faced up to a difficult financial outlook, in uncertain times, and we have made hard decisions in the interests of that future. We have cut bureaucracy, we have trimmed low value-added work from our agenda, we have reduced the costs of operations. We have achieved substantial savings through this effort, and I am proud of the NASA team for how responsive you have been and for how hard you have worked.

I think we have a better program as a result of this exercise. We are a leaner but stronger agency. We have shown that we can accept tough challenges and meet them. We have done it with our budget. We have done it with the reordering of priorities within that budget. And we have done it with the space station, the Space Shuttle and our other science and technology programs.

Consider some of the achievements we have produced over the last 18 months.

The Space Shuttle continues to fly, and fly safely, at a reduced cost to the nation. Overall, between 1991 and 1998, we will have cut the cost of flying the Space Shuttle by 43%. We are looking for further efficiencies, for better and cheaper ways of doing business. But safety remains our number one priority.

Under the leadership of President Clinton, we are now ready to move into the new space station era. With the President's guidance and support, we have dramatically reshaped the space station program. Last year we successfully accomplished a major redesign. Over the period from Fiscal 1994 to 1998, we reduced funding requirements by $6 billion.

We have reached out to other nations and reacted to the historic trends of our time. We have reached out to Russia and are working to forge a new and dramatic partnership in space. From cooperative flights onboard the Shuttle and the Mir space station to a joint program to develop the international space station facility, we are on the verge of a new and exciting era in the history of the Space Age. Just last December in Moscow, NASA and the Russians signed a Memorandum of Understanding to cooperate in eight areas in fundamental aeronautical sciences.

We have made great strides toward bringing NASA's programs into balance. There is a balance between big science and small science. There is a better balance between human and robotic spaceflight. There is a better balance between operations and technology. There is more money for aeronautics. There is an increased emphasis on the Mission to Planet Earth and bringing new technology into the American workplace.

We have made substantial changes at NASA, but there is more work ahead. We must continue to strive for an important set of goals and missions. Our priorities must continue to provide relevant returns to the American people. I believe we have a bright and wonderful future in the continued exploration of air and space. We continue to excite, to inspire, to lead the way to new developments and new adventures. Working together, we will push on to the next horizon.

—Daniel S. Goldin

CONTENTS

winter 1994

Cover: Alan Chinchar, a Houston artist who has participated in the NASA Art Program over the years, has been artfully documenting the astronaut/cosmonaut training for the STS-60 mission. Our cover features his pencil sketch of Sergei Krikalev (foreground) and Vladimir Titov being photographed in JSC's Shuttle simulator. Other Chinchar sketches can be found throughout the "Partners" article beginning on page 8.

features

8
PARTNERS
The STS-60 mission may mark the beginning of a long and fruitful relationship between the Russians and the Americans.

18
FLYING FRIENDLIER SKIES
With help from NASA, the U.S. general aviation industry may be flying high again.

14
COMING IN ON TWO ENGINES AND A PRAYER
Dryden engineers believed a computer program could help guide a plane to a safe landing; they were right.

22
A QUESTION OF GRAVITY
Animal research at the Ames Research Center may help scientists understand the basic role gravity plays in human health.

26
MARS ON HOLD With the loss of the Mars Observer last summer, NASA is making plans for a return to the Red Planet in 1996.

departments

2
Spectrum

6
Inside the Beltway

7
Off Hours

30
Center Select

32
Down to Earth

33
Countdown

NASA MAGAZINE

Acting Associate Administrator for Public Affairs
Geoffrey H. Vincent

Acting Manager of Internal Communications
Beth Schmid

Editor
Beth Schmid

Staff Writer
Doug Isbell

Editorial Consultant
Tony Reichhardt

Editorial and Production Assistant
Sonja Alexander

Design
Steve Chambers

Art Director
Robert Schulman

Staff Photographer
Bill Ingalls

NASA MAGAZINE is published quarterly by the National Aeronautics and Space Administration for the information of the Agency's employees. Contributions and comments are solicited from Headquarters and all field centers, and should be addressed to Editor, NASA MAGAZINE, Internal Communications, Code P-2, NASA Headquarters, Washington, DC 20546.

Opinions expressed in articles are those of the authors and do not necessarily reflect agency policy.

NASA MAGAZINE is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402

NASA MAGAZINE is printed on recycled/recyclable paper.

LDEF Returns

The Langley Research Center is disassembling the Long Duration Exposure Facility (LDEF) free-flying spacecraft in preparation for its expected relocation in 1995 to Florida's Spaceport USA, where it will be reconstructed for permanent display. Spaceport USA, the Kennedy Space Center's visitor center, receives an estimated two million visitors each year. The Langley-built LDEF, which spent 5 1/2 years in orbit testing the effects of the space environment on different materials, carried 57 experiments, including 13 million tomato seeds that were shared with educational institutions around the world after the spacecraft's return to Earth in 1990. The facility is shown here being moved to the building where it is being disassembled.

Home Movies

Varied Directions International, a television producer in Camden, Maine, is seeking images of projects Mercury, Gemini and Apollo covering the period from the 1950s to 1976 for a television series on the history of NASA's space program. The company is looking for home movies, interviews with astronauts or photographs.

The series will tell the story of the early space program from the astronauts' perspective. The producers are particularly interested in unusual or emotional material, or in photographs of the astronauts that could accompany anecdotes. For more information, contact Daniel Levitt at Varied Directions, 69 Elm St., Camden, Maine 04843 or call collect to (207) 236-8506.

January 1993: Dante on the brink of an Antarctic volcano.

Dante, Take Two

NASA, the Alaskan Volcano Observatory (AVO) and Carnegie Mellon University have agreed to send Dante, the eight-legged robot that attempted to explore Mt. Erebus in Antarctica last year, on a second expedition to a live volcano this spring. This time Dante is to descend into the crater of Mt. Spurr, about 90 miles west of Anchorage, Alaska, for geophysical and geological sampling. The test also will evaluate several modifications to the robot that may be used in a possible second attempt to explore Mt. Erebus. Mt. Spurr, which is considered too dangerous for human exploration, erupted three times in 1992 after being dormant for 39 years. The expedition will test Dante's ability to traverse escarpments, deploy scientific equipment and gather gaseous samples. The test also will help planners of NASA robotic missions design systems that could be used in remote planetary exploration.

High-Tech Smorgasbord

Technology 2003, the fourth annual national technology transfer

conference, showcased America's best technology in Anaheim, Calif., in December. The conference, which has tripled in size since its inception in 1990, has grown due to increasing government and industry recognition of technology transfer as a key to economic growth. Sponsored by NASA, *NASA Tech Briefs* magazine and the Technology Utilization Foundation, the goal of the yearly conference is to help U.S. companies take advantage of the many technologies produced by more than 700 federal labs. NASA's main exhibit at the conference included a scale model of (and technology "spin-offs" from) the National Aero-Space Plane, as well as spin-offs in the areas of medicine, sports and recreation, safety, home and industry. A 16-monitor videowall also featured examples of technology spin-offs. Every NASA Center had an aerospace exhibit at the conference this year.

Sun Searcher

A solar-powered electric car built by students and faculty at California State University, Los Angeles campus, with technical and financial support from the Langley Research Center's Education Office, placed 13th out of 54 finishers in the 1993 2,000-mile World Solar Challenge III race held November 7 in Australia. The Solar Eagle II is environmentally safe, according to its builders, and was built entirely with volunteer labor. The car can travel at 50 mph, although its average speed during the six-day race was 37 mph. The car finished the race two days faster than it did in 1990, and beat its average speed by more than 9 mph. The winning car, a Honda, broke the old race record of 41.5 mph with an average of 52.5 mph. The Solar Eagle II is one of many Langley programs aimed at supporting minority colleges and universities.

Pictured, left to right, are Chivey Wu, professor of mechanical engineering at California State University, Los Angeles, and Robert L. Yang, Assistant University Affairs Officer at the Langley Research Center. The character in the middle is a one-sixth scale model of the Solar Eagle II.

The Big Hook-up

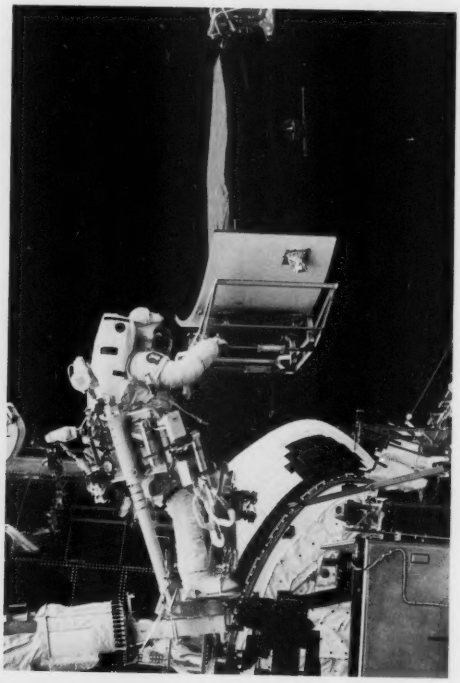
Beginning in January, U.S. and Russian scientists will be able to communicate with each other directly over an international computer network set up by the Ames Research Center. The NASA Science Internet (NSI) link will connect research sites in the United States with Russia's Space Research Institute (IKI) in Moscow. An additional nine Russian space-related institutions, including the Astronomical Institute, the Institute of Biomedical Problems, the Gagarin Cosmonaut Training Center and NPO-Energia, will be connected to IKI to form a new Russian Space Science Internet. The NSI link to Russia supports 15 collaborative science programs in the first phase of the project, including research in life sciences, Solar System exploration, astrophysics, space physics and Earth sciences. The NSI is the electronic backbone of NASA's scientific computing network, which connects 150 sites and more than 40,000 NASA researchers and scientists around the world. •

TRANSITION

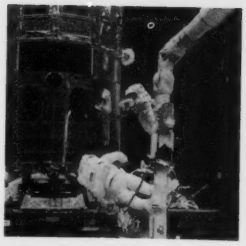
Note from the Editor:

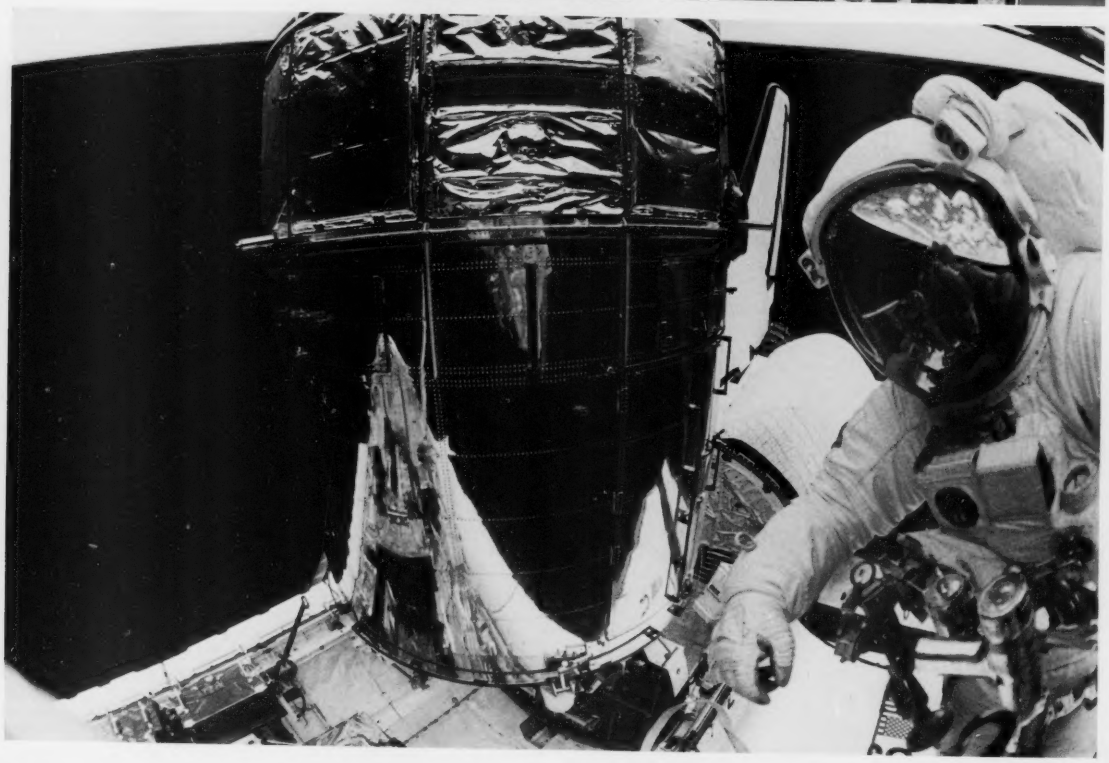
This issue of *NASA Magazine* is our last one. In an effort to deal effectively with budget cuts, it was decided that it is no longer feasible or cost-efficient to continue the publication. I appreciate the input and support I have received from so many NASA employees and contractors.

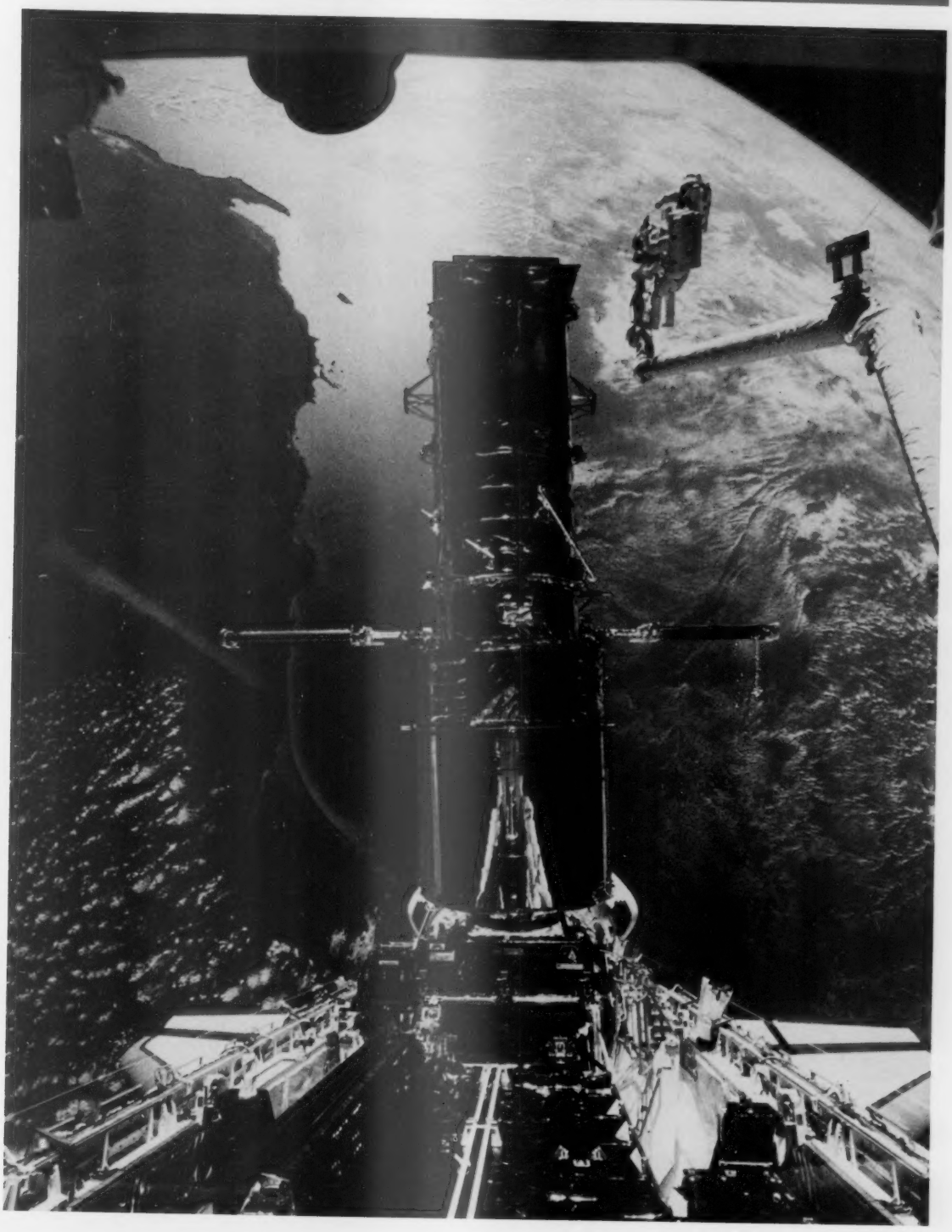
—Beth Schmid, Editor



The STS-61 flight crew left to right , top, Story Musgrave, Jeffrey A. Hoffman, Kathryn C. Thornton, Tom Akers; bottom left to right, Claude Nicollier, Kenneth D. Bowersox, and Richard O. Covey. Together with controllers at Johnson and Goddard, they completed all of STS-61's servicing objectives.







Congress recently overturned a 54-year-old law that prevented federal employees from participating fully in the political process. You still can't run for office, but at least you can campaign for your favorite candidate.

Down the Hatch

by Dr. John Lawrence,
Office of Legislative Affairs,
NASA Hq.

It may have seemed like an ordinary autumn evening. Perhaps you were comfortably at home, blithely enjoying a tuna casserole, when the U.S. Congress restored many of your important civil rights.

For 54 years, federal employees have been constrained from participating in partisan politics by the Hatch Act. The law takes its name from then U.S. Senator Carl Hatch of New Mexico, who sponsored the legislation. Congress passed the act in 1939 after discovering that some federal workers were being forced to give money to political candidates in order to keep their jobs. As a result, nearly three million of us have been prohibited from such activities as running for partisan office, making campaign speeches on behalf of candidates, collecting contributions, selling tickets to fund-raising events and organizing political rallies or meetings.

The House Post Office and Civil Service Committee had been trying to revise the Hatch Act for almost two decades. The present bill passed by a vote of 339 to 85 in the House of Representatives, and by 68 to 30 in the Senate. Opinion on the measure split along party lines, with most Democrats in favor and most Republicans opposed. Observers explain that Democrats are generally supported by employee unions and could stand to benefit from the increased activism. Republicans may be more likely to regard the proposal as a union power play.

As a compromise, the new, looser rules do not apply to employees in law enforcement, national security, the Senior Executive Service (SES) and other sensitive jobs. The close working relationship between the SES and political appointees, or so the logic goes, could make them more vulnerable to partisan manipulation if they were allowed to participate more fully in the political process. Approximately 85,000 employees remain covered by the original Hatch Act constraints.

While the liberalized law extends more political freedoms to civil servants and postal employees, workers are still restricted from running for any political office on a partisan ticket, politicking on the job, or coercing subordinates for partisan reasons. However, it is now possible to hold office in a political party organization, for instance as a county chairman or delegate to a presidential nominating convention. Workers may now attend partisan political meetings, work on campaign telephone banks, and distribute campaign materials away from the workplace. They can also—away from the workplace—endorse candidates and solicit votes on their behalf. Federal workers may not, however, solicit campaign contributions directly for candidates. Such solicitations would be restricted to asking for donations from fellow members of a federal employees political action committee (PAC). Supervisors also cannot solicit PAC funds from subordinates.

Another byproduct of this legislation is an unrelated provision that permits agencies to tap federal paychecks to satisfy personal debts. Paychecks can be garnisheed right now, but only to pay off debts owed the federal government, or to satisfy alimony and child support payments ordered by state courts. This new provision will oblige agencies to honor any court-ordered payments including, for example, money owed to car dealerships, appliance stores, individuals, hospitals and others. Federal paychecks have previously been immune to such collections. In addition to helping creditors collect debts, the government would charge two percent of the amount to cover administrative costs.

Expected effects of the revised Hatch Act on political America? —not much. The Merit Systems Protection Board polled 13,000 federal workers and found that about 30 percent desired looser rules, 30 percent did not, and 40 percent had no strong opinion. The results were virtually identical to a similar study done three years earlier. SESers were polled to measure their attitudes toward being excluded from the new rules. Most didn't care.

Penalties for Hatch Act abuses can still be severe—fines, suspension, and even loss of job. Accordingly, the Office of Special Counsel has established a hot line to answer questions about the new limits for political activities. The number is, of course, 1-800-85-HATCH. •

Ames Research Center's Seth Anderson is not about to come down to Earth. At age 75, he's still flying high.

The Soaring Seventies

by Beth Schmid

Don't even *think* about telling Seth Anderson to take a flying leap: He just might do it, and he knows how to land. This tall, thin, fit-looking Ames flight research engineer can make you feel old just *hearing* his daily routine.

Anderson began his aerospace career in July 1941, having just graduated from Purdue. At the Langley Research Center, he applied his newly acquired aeronautical engineering skills to the war effort. After returning to Purdue for his master's degree, he came back to NACA (the National Advisory Committee on Aeronautics, NASA's forerunner) headquarters in the summer of 1942 to inquire about career opportunities.

He was told that although there was a new lab on the West Coast called the Ames Aeronautical Laboratory, there were no job openings. Anderson didn't buy that, so he hitchhiked all the way to Mountain View, Calif., to check it out for himself.

"I walked through the door and they said, 'Where would you like to work?'" he recalls.

He's still there more than fifty years later.

I first "ran" into Anderson at last summer's Experimental Aircraft Association (EAA) Annual Fly-In and Convention in Oshkosh, Wis. As my husband and I returned from our morning run, we saw Anderson in the hotel lobby. He told us he had finished *his* daily run about an hour before, which would have put it somewhere around 5 a.m. Later that day, I asked him if he had been running for long.

"Every morning for the past 28 years," was his immediate and energetic reply.

In fact, he claims to have run 1 1/2 miles every day—*without exception*—since August 15, 1965. On top of that, he tries to swim and weight train for another two to three hours a day. No wonder he has 5,000 hours of accumulated sick leave.

Anderson has been coming to the Oshkosh air show to give technical talks every year since 1975, when he says the NASA exhibit was housed in a "little tent with minimum facilities." He was the first NASA employee to give a technical talk at Oshkosh, and he still loves doing it.

Part of Anderson's motivation for his daily running, weight training and swimming routine is to maintain the strength for his latest (since he turned 60) hobby: hang gliding. He admits that it was a tough sport to learn at that age, particularly since the hang gliders of 15 years ago were more difficult to launch and land. It didn't deter him, though.

"You need to have the strength to lift the hang glider off your car, carry it up to the launch point, and then run fast for a good launch and landing. Surprisingly, it doesn't take guts, it takes skill," he says.

Anderson recently celebrated his 75th birthday by flying his multicolored, 70-pound hang glider for the 140th time in Yosemite National Park. He took off at Glacier Point from a boulder overlooking Yosemite Valley, approximately 4,000 feet below. (The Empire State Building is 1,250 feet high).

Didn't scare him.

"If you were a bird in a former life, you're going to feel okay," he says.

If Anderson isn't exercising or hang gliding in his off hours, you might find him flight-testing the BD-5 experimental aircraft that he built using NASA technology (of course) and a Honda Civic engine. Currently he is installing a surplus turbine engine to further improve the aircraft's performance.

"I'm trying to alert people how NASA's technology can be applied to general aviation-type aircraft as well as to other types," he says.

All in a day's play. •

Partn

The flight of a Russian cosmonaut on the Space Shuttle could be, like the old movie said, the beginning of a long and beautiful friendship.

ers

Sergei Krikalev: first cosmonaut to fly on the Shuttle is portrayed in pencil by Alan Chinchar for the NASA Art Program. Inset, left, Sergei Krikalev, inset, right, Charles Bolden: STS-60 Commander.

Sergei Krikalev says he doesn't think of himself as an historic figure. But this winter he will become the first Russian cosmonaut to fly on the Space Shuttle—opening a new era of cooperation between the two former space rivals.

The 35-year-old Krikalev has logged more time in space than any other person except his colleague Musa Manarov. In 1988 he spent five months onboard the Mir space station, then returned for a ten-month stay in 1991, during which he watched the breakup of the Soviet Union from his perch high above the planet.

For more than a year, he and his backup Vladimir Titov have been in Houston training for the upcoming STS-60 flight onboard Discovery. During that time, the rest of the mission's crew—Commander Charles Bolden, Pilot Kenneth Reightler, and fellow Mission Specialists Franklin Chang-Diaz, Jan Davis and Ronald Sega—have become something of a Krikalev fan club.

"He is probably the best ambassador the cosmonaut program could have sent here," says Chang-Diaz, while Reightler remarks with a trace of envy, "I'm real proud of my five days in space—and he's got fifteen months!"

Krikalev and STS-60 Commander Bolden took time out from their busy training schedules in November to talk to Johnson Space Center public affairs specialist Rob Navias about their historic flight. Edited versions of those interviews are printed here.

—Editor

Sergei Krikalev

After spending more than a year in orbit and performing seven spacewalks on two missions, what type of experience do you bring to this crew and this particular mission?

This is a different mission, because it is short-duration, a relatively big crew, and another vehicle. So some experiences [of a cosmonaut] may not be applicable for Space Shuttle. But some are—[like] our point of view on experiments, or on safety, or schedule. We exchange opinions with our crewmates, and this exchanging of experiences is interesting for both sides.

What was your reaction when you were selected along with Vladimir Titov to come here and train to fly on the Space Shuttle?

It was less than half a year after my long 10-month flight, but it was very exciting for me, because I knew it would give me other experiences and knowledge about spaceflight. So I thought it would be interesting. And I have found that it is.

Let's discuss the differences between training for the Space Shuttle and training for the Mir.

Our crews fly twice per year approximately, our flights are longer and we have more experiments. It looks to us that we have more feedback from the crew on experiments—on the sequence of experiments, on the flight schedule and on the flight program itself.

Some differences are easy to explain, because we're flying different vehicles. The Soyuz vehicle flies and docks with the station in just a short period of time, and so most of the time is spent on the space station, when we usually don't change our orbit. Sometimes we could use our Soyuz vehicle as an emergency vehicle, but it's just a small part of a big job.

Another difference is that we fly in crews of two or three, usually. And in this case, we know all the experiments. [If] I am the prime [crewmember] on some experiments, my partner will back up for

Chinchar captures Krikalev in a quiet moment.

me. And in cases where he is a prime, I will be a backup. Because we have six crewmembers [on the Shuttle] we can divide our job, and one, two or three crewmembers could be very familiar with one system or experiment. And the others could just have a "big picture."

Does it seem like an eight-day mission is kind of simple in comparison to your longer missions?

It's simple from one point of view, because it is a short-duration flight. For us, it's unusual to hear about "long-duration" flights on Space Shuttle [that last only] 12 days or 14 days. All of those flights, from our point of view, are short-duration flights. But from another side, it's not easy for us. It's a new language, new systems, a new ideology of [designing] experiments. When I start to work with a new experiment in Russia, we have some kind of standard interface between equipment and crew. In this case [the Shuttle] it's a little bit different. Again, it is interesting for us to get this kind of new experience.

How challenged have you felt stepping into this new environment?

It was difficult—a difficult year for Vlad and me. And one of the reasons is the short period of time that we had to study. We had to study a lot of systems. We had to study language, and all this came at the same time. And the period of time was very short for the volume of knowledge.

How have you and your family adapted to life in the United States?

Of course, my wife and I and even my small daughter have been homesick. I miss my friends, my relatives. [Before my] long duration flight, it was a long time preparing. And then [came] the flight. And then a relatively short rest. [Now] it's like the flight for me again. I'm away from my home, and I'm in an unusual environment with a 12- to 14-hour working day.

You said earlier that at this point in your career you did not feel as if you were a part of history. But your pilot, Ken Reightler, says that your presence onboard the Shuttle is in fact a history-making event, because it opens up a new avenue of joint cooperation. Do you sense that?

I hope it will open a new kind of relationship and new thinking. Even a few years ago it was very difficult to imagine that somebody from America would visit our environment and train in our space program, and somebody from Russia would come to NASA and train in this restricted access environment. So I think it is a good idea. But I don't know [about] history. For me when you talk about history, I [think about] the bones of dinosaurs. I don't think I'm a dinosaur yet.

STS-60—Titov and Krikalev.

Charles Bolden

Is one byproduct of this flight that we've learned something from Sergei and Vladimir that will allow us to understand Mir better and make our astronauts' experience much easier when they get over to Russia to begin training next year?

I think definitely that will be the case. And I'll give you some concrete examples. As a [mission] commander, I realized from the beginning that I had some very, very valuable assets in the form of these two people. And I wanted to make them available to the [U.S. space] community as much as possible, with a minimal impact on our training. So what we have tried to do is find little chunks of time where [the cosmonauts] could go out and associate with the rest of the space community here. Sergei, for example, recently spent about two hours with our inflight maintenance folk, just giving them a presentation on some of the inflight maintenance types of things that he accomplished in his 15 months on Mir. They were beside themselves. They saw similar techniques, but they also saw some things they had never even thought about.

To me it would be stupid to bring such talented people as Sergei and Vladimir here and not utilize that talent in helping to educate us—me, the trainers, the flight controllers and everybody—with all the experience they have. They have more time walking in space than we have almost in our whole space program. So I think it would be very unwise not to utilize the talent.

Is STS-60 the vanguard in creating the atmosphere that will be the cornerstone of a joint space station effort?

...I think this was the ice breaker. We think this is the way we want to operate on space station. But it ain't going to be that easy unless people are willing to modify their thinking, and unless people are willing

Titov in a T-38.

to admit that "they" are just as important as "we" are, and that everybody has something to bring to the table. So let's not try to slight anybody. Let's not think that *we* know what's best, and just say "We'll tell you what to bring." Because it'll never work if you try to do it that way.

We're talking about trust, right?

...You're right. The way that our crew is organized is drastically different from the way we've ever done it with a non-American astronaut. Sergei and Vladimir are training as mission specialists. And people keep making the mistake that, "Oh, well, you have Russian Payload Specialists." No, we don't. We have two guys who are training as members of the Shuttle orbiter crew, not as payload crewmembers. In the case of Sergei, he is my prime inflight maintenance person. He is my prime RMS [Remote Manipulator System] operator for the grapple of the Wake Shield Facility [a device to create a high-quality vaccuum for experiments]. If I don't trust him and his abilities, I'm in trouble, because he is an integral part of my crew. In our simulations we always have things break. We hope it won't happen in flight, but in the simulations we've already had cases where we've had to do extensive inflight maintenance. And I couldn't go and hold his hand. Sergei and somebody else from the crew who wasn't even trained for inflight maintenance had to go heading off and coordinating with the ground. And he has done that superbly. He has been extremely helpful to us in developing the specific procedures that we're going to use for the remote manipulator system. So hopefully he trusts us as much as I trust him. And I think that's vital.

Tell us how you have bridged the cultural differences [between the astronauts and cosmonauts]. How might history record your flight?

I think, quite honestly, that history will forget the *flight*. And history will record, in detail, what happened in the 12 to 13 months *leading up to* the flight, because it's been during this time, since last October when Sergei and Vladimir came to America, that we have been able to demonstrate that we can in fact work together as a team. And I think we have done that very well.

Having Sergei and his family and Vladimir and his family come here, with several members of each family not speaking any English, and getting them integrated into a community where people have accepted them and have become very good neighbors to them—I think that is the critical part about the whole flight.

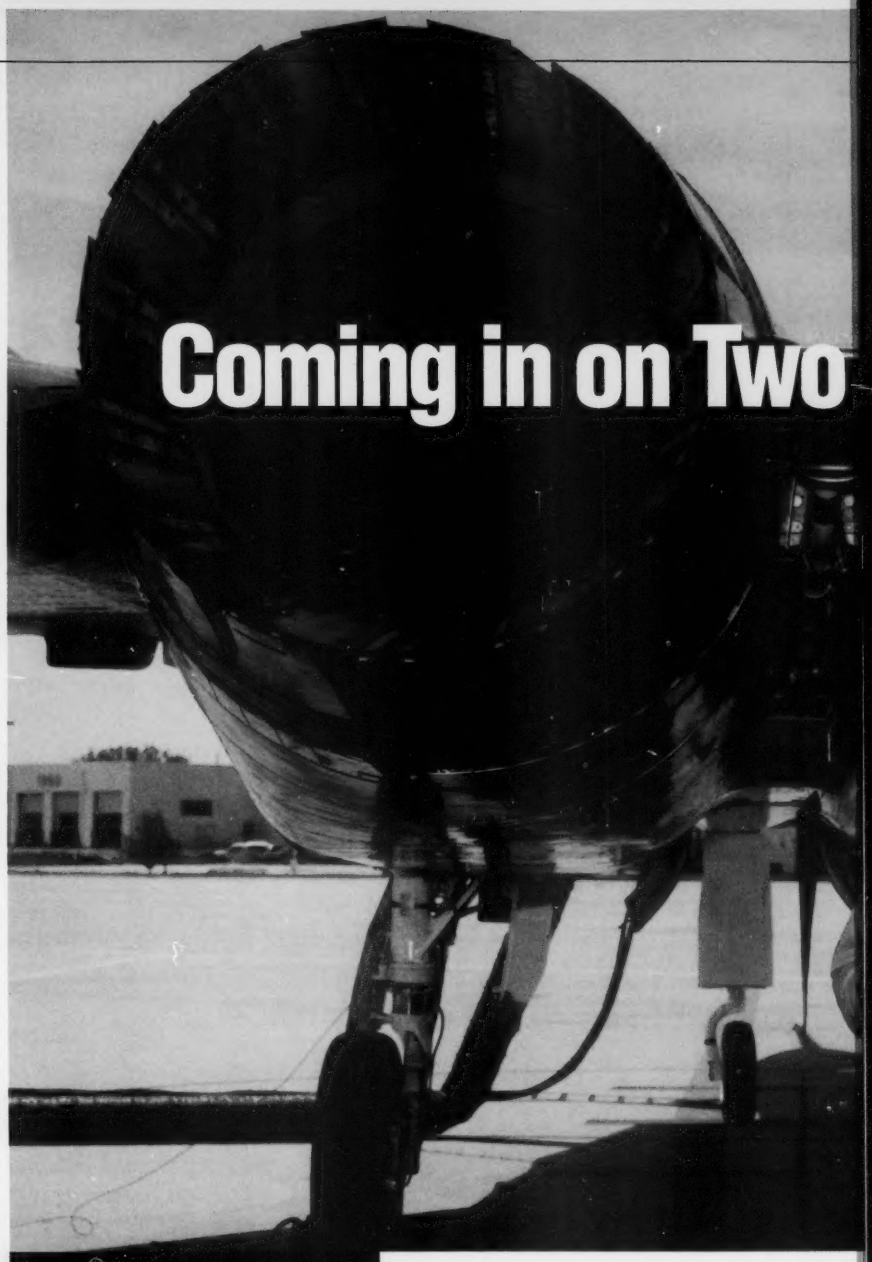
So when it gets down to it, people may not even remember the flight 20 years from now. But they will be able to look back, I hope, and say this crew of people from two very different countries helped to prove that all these things we thought we could do—all this Star Trek stuff, you know, where people live together and work together from different planets, not just countries—really can be done.

Do you think this joint cooperation is the only way space exploration can thrive in the future?

The things that I would like to see the space program do—go back to another planet, which right now seems like Mars, go back to the lunar surface—are only practical to do in partnerships of spacefaring nations, from a financial standpoint. And what better way to do it than by partnering up the two leaders in the space challenge—the United States and Russia—to make that happen. And I think the sooner we can effect this marriage and get things working smoothly, the sooner we'll be on our way to Mars or to some other planet. •

All artwork for this story was provided courtesy of NASA Art Program artist, Alan Chinchar.

Coming in on Two



The pilots of United 232 were enjoying a routine flight as their DC-10 jumbo jet cruised over the Midwest farmlands. Suddenly a shudder ran through the airliner. By reflex, the pilots grabbed their control columns...and found them dead in their hands.

The tail-mounted engine had blown itself apart, severing hydraulic lines with shrapnel. The crippled aircraft's flight control surfaces were useless. No rudder. No elevators. No ailerons.

The fate of 296 people rested on the pilots' ability to get the DC-10 on the ground safely. Now their only way to steer was by jockeying the thrust of the jet's two remaining engines....

Bill Burcham put himself in the cockpit of that ill-fated airplane a hundred times in his mind. What if the pilots had juggled the throttles *this* way instead of *that* way, he wondered. How could they have squeezed just a little more control from the engines and avoided a crash?

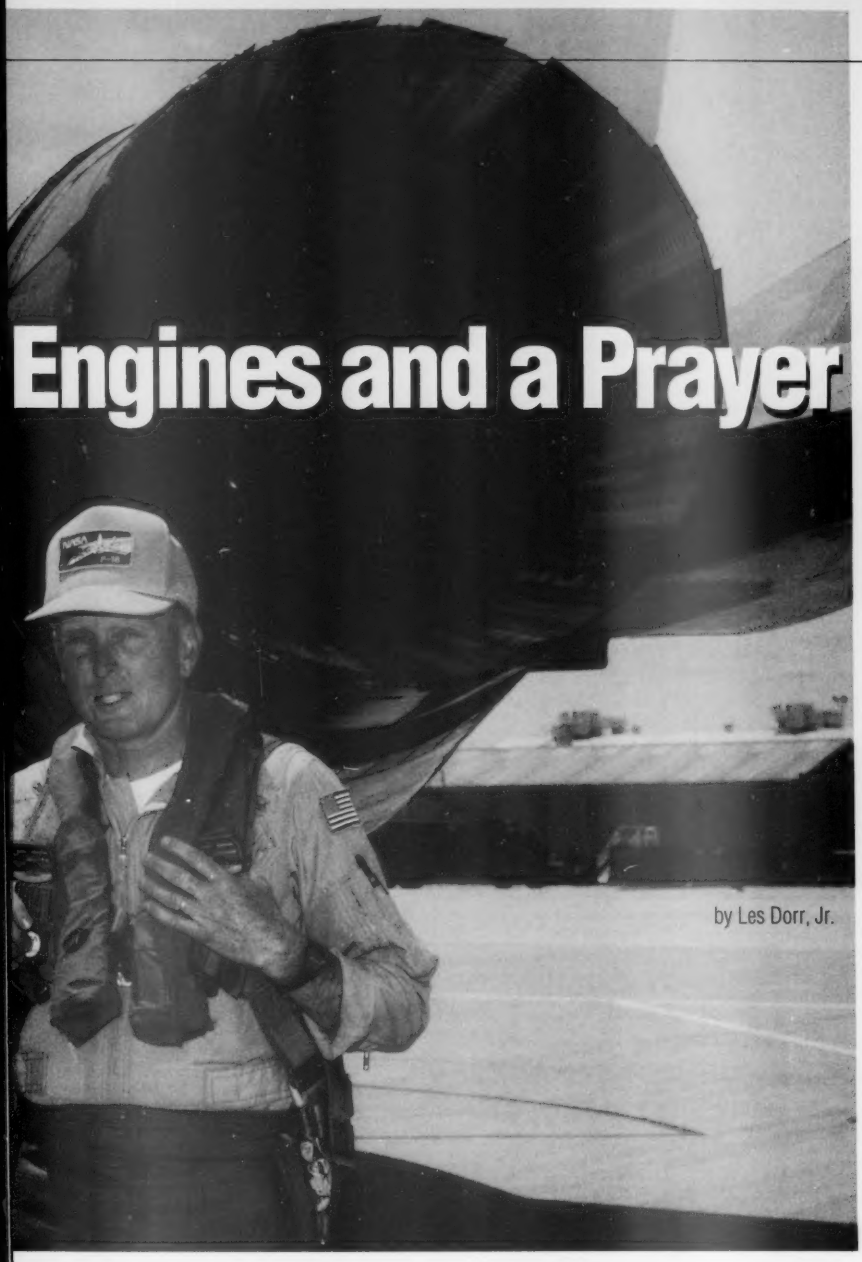
Then the Big Eureka came to him: What if they had had a program in their flight computer that could *automatically* control the engines and fly the plane to a survivable landing?

The heroic performance of the pilots in the 1989 incident, which 185 of the passengers and crew survived, was the catalyst for a three-year research project by Burcham—almost a personal crusade, really—to create a computer-assisted method of safely flying and landing an aircraft whose flight controls are disabled.

Now the chief of aircraft propulsion at NASA's Ames-Dryden Flight Research Facility, Burcham had spent almost his entire 28-year NASA career studying, developing and testing aircraft propulsion systems. For half that time he had specialized in what engineers call "propulsion integration": making planes and their powerplants work together more efficiently.

Dryden engineers were convinced that a computer program could help guide a plane to a safe landing, even if its control surfaces failed. They were right.

For example, Burcham had done research on the SR-71 Blackbird (bogusly called the "YF-12C) that NASA flew on high-speed missions from 1972 to 1978. More recently, he was involved with digital engine



Engines and a Prayer

by Les Dorr, Jr.

NASA research pilot and ex-astronaut Gordon Fullerton with NASA's F-15 after landing it using only engine power.

control studies using a specially modified NASA version of the Air Force's F-15 fighter.

Burcham's starting point for testing his idea of controls-out computer software was Dryden's electronic flight simulator. In his spare time, nights and weekends included, he tried to "fly" computer models of the NASA F-15 without using the standard rudder, elevators and ailerons. By varying the power level to both engines, Burcham found that he could make the plane's nose slowly rise or drop. Increasing power in one engine while backing off on the other produced a bank and turn.

But piloting the F-15 manually with just the throttles was a real bear.

"You could hold altitude within a few hundred feet and direction within a few degrees," Burcham recalls, "but you couldn't get down to the runway. Still, I got the feeling that an automated system could do the job pretty well."

To help with the simulations, Burcham enlisted ex-astronaut Gordon Fullerton, one of NASA's premier research pilots. Fullerton had flown about 13,000 hours in more than 100 different airplanes, from big jet transports to hot fighters. In his spacefaring days, he had piloted the prototype Space Shuttle orbiter Enterprise on three approach and landing tests, and had flown on two highly successful Shuttle missions.

"Bill called down the hall one day and asked me if I'd work with him," Fullerton remembers. "It wasn't a defined program, just he and I sort of messing around."

Fullerton agreed, however, and set to work. After many tries, he could manhandle the simulated F-15 to the runway using only the throttles. ("Just like a video game!" he says.) But it was obvious that a pilot coping with a real controls-out emergency for the first time wouldn't make it. He later tried manipulating the engines of about 10 other actual aircraft at a safe altitude, with the same results. There was plenty of power to maneuver, but not enough precision to land.

Burcham turned back to the simulator, where Dryden engineers had developed and installed a rudimentary version of his Propulsion Controlled Aircraft (PCA) software, which figured out how to move the throttles after Burcham programmed in the flight path.

Last April, NASA's F-15 touched down for the first time using only engine power for control.

The computerized control system was an immediate hit with the NASA pilots who tried it, even in its early form.

"We got lots of crashes with manual throttle control, lots of happy landings with PCA turned on," says Burcham. "All the pilots made it on their first try."

Fullerton then took center stage with a series of missions in the NASA F-15 to see how an actual airplane performed under manual control, and to pave the way for possible flight tests of the PCA system. It turned out to be a "sorry-flying machine," he recalls, far worse than the simulator predicted.

The reason was that the simulator had modeled an *ideal* F-15, with mathematically identical performance from the two engines and no disturbances from airflow into the inlets.

In a real F-15, each engine puts out minutely different levels of thrust, and there is a slight lag in engine response when the pilot moves the throttles. The aircraft's augmented control system normally accounts for these effects and gives the pilot a smooth ride.

Although Dryden's simulator worked fine as a training tool for normal missions, it didn't come close to simulating a real F-15's performance under manual control. Matching the actual aircraft's characteristics with the simulator became the single biggest obstacle to continuing the PCA project.

By varying the power level to both engines, Burcham found that he could make the plane's nose slowly rise or drop.

For six months Fullerton would take the F-15 up for maneuvers, then help Burcham and engineers from NASA and McDonnell Douglas, the plane's manufacturer, refine the computer models. The whole process took almost a year.

"We fought that battle until the plane retired [in November 1993]," says Burcham. "We probably never had a perfect simulation."

When he and Fullerton felt comfortable with the matchup, PCA software programmed by McDonnell Douglas was installed in the F-15's flight computer. Two thumbwheels were mounted in the cockpit. Rolling one forward or backward commanded the system to lower or raise the nose; moving the other from side to side made the plane bank.

Engineers also added new symbols to the electronic "Heads-Up Display" that sat just behind the F-15's windshield. A lighted box would move to reflect the thumbwheel inputs, and the aircraft's response to the commands was shown by a small airplane symbol. Theoretically, the pilot could line the box up with the end of the runway, then sit back and watch PCA cruise to a perfect landing.

In February 1993, Fullerton made the first PCA flight. The normal control surfaces weren't turned off ("Would've made a better movie," he jokes), but the augmentation system was disabled. In other words, he could grab the stick if PCA didn't work as intended.

Good thing, too, because the system responded "less than wonderfully" on the first flight and for several more flights after that. In response to Burcham's suggestions radioed from the ground, Fullerton punched different numbers into the plane's computer keyboard to fine-tune the PCA system. It was a process of trial and error.

"Some changes were total disasters, and I had to take over the aircraft," says Fullerton. "It took nine

or ten flights before PCA was to the point where we could go for an actual landing."

The last 20 feet or so were the hardest, thanks to the "ground effect" phenomenon. Burcham and Fullerton knew that as the F-15 neared the runway, air from the ground would push up on the plane's horizontal tail, which would make the nose drop. The plane's response to commands from the PCA system might not be quick enough to prevent a hard touchdown that could damage the F-15's landing gear.

When McDonnell Douglas tested for ground effect in their F-15 simulator, the plane crunched into the runway every time. But Fullerton's test-pilot instincts told him the situation wasn't nearly so drastic, so on a couple of PCA flights he took the plane down to 10 feet, froze the control stick and studied what happened. He was right: The ground effect was only about half as bad as predicted.

On April 21, 1993, Fullerton climbed into the air to attempt a PCA-controlled landing. As he descended, everything seemed to click. The system made the F-15 respond effortlessly as he diddled the thumbwheels to line up with the runway.

Fullerton's regular breathing sounded over the radio circuit. There was no excitement, no surprises. It was almost a milk run.

"The approach is just as good as you could ask for," he boasted.

Down through the last 20 feet, the ground effect steepened Fullerton's shallow glide path. With a firm *blip! blip!* the F-15's tires touched the runway. He gently grabbed the control stick, immediately lifted off and flew away for a second go-round. PCA did the trick again, bringing the plane through what looked from the ground like a perfectly normal landing.

Gordon Fullerton, left, and Bill Burcham.

Burcham was elated, but it was almost an anticlimax.

"We got lots of crashes with manual throttle control, lots of happy landings with PCA turned on," says Burcham. "All the pilots made it on their first try."

"I felt we had proved the system even before taking it all the way down," he says. "In an emergency, where you wouldn't worry about saving the gear, I was sure you could land."

Fullerton made several more flights to improve the PCA system, especially the pilot's workload during banking maneuvers. Concerns about busting up the F- 15's gear with an out-of-limits touchdown precluded any more landings, though.

For the last five PCA flights, Fullerton yielded the cockpit to guest pilots from NASA, the Air Force, Navy, the USAF test pilot school and McDonnell Douglas. Tom McMurtry, Dryden's flight operations chief, got the final ride.

On those missions, the pilots put the F-15 in a 90-degree bank and a steep dive, then engaged PCA. The system easily brought the nose up, rolled the plane to the proper position and controlled flight path oscillations. The pilots then went on to complete an approach to the Edwards Air Force Base runway.

"It proved that you don't need hours and hours of training to operate PCA," says Fullerton.

Now that NASA has done the high-risk technology development, industry could take PCA—after more testing—and apply it to other aircraft, particularly multi-engine transports. Burcham thinks the system even has the potential to replace mechanical backup systems.

"It's just computer software, so there are no real maintenance and reliability issues," he points out.

Nothing would make Burcham prouder than for companies to take PCA and run with it. Still, he has mixed emotions.

"Yes, I hope to see it incorporated into future aircraft designs," he says. Then, after the briefest pause, he adds, "I also hope it never has to be used." •

Les Dorr is a regular contributor to NASA Magazine. *His last article, on airplane icing, appeared in the Spring 1993 issue.*

Flying Friendlier Skies

by Douglas Isbell

How eager would you be to drive a car that relies on technology from twenty, thirty or even forty years ago? What kind of market would exist for such cars if you wanted to sell them?

This is the dilemma facing the U.S. general aviation industry today. Since the boom years of the mid-1970s, U.S. companies have been driven out of the small piston-powered airplane business in droves, due to a combination of technological obsolescence, increasingly complex air traffic, rising luxury taxes and gas costs, and imposing product liability regulations.

While some firms retooled to build potentially lucrative business jets, many others simply went out of business. As a result, annual production of U.S. general aviation planes has fallen to about five percent of its 1978 level.

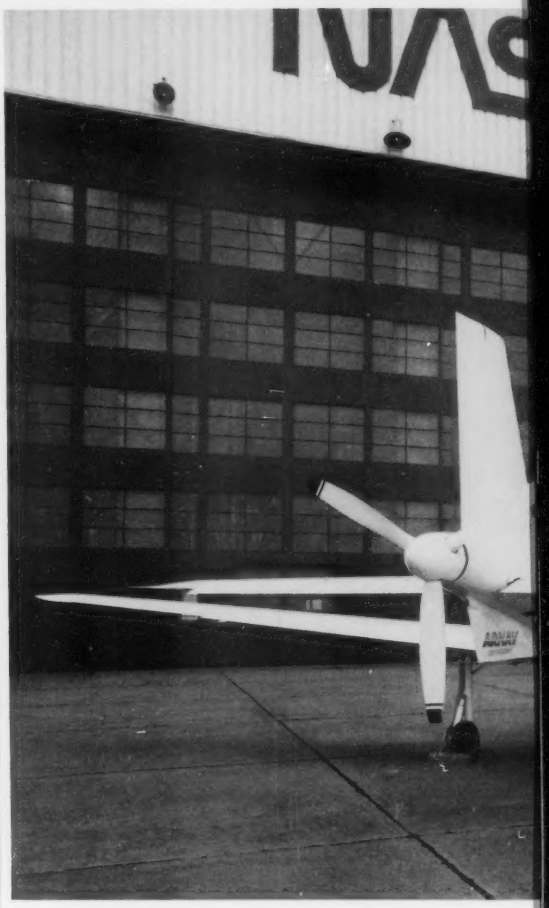
"General aviation as we knew it from the 1950s through the 1980s is in danger of disappearing," according to Bruce Holmes, general aviation program manager at NASA's Langley Research Center.

NASA Administrator Daniel Goldin and other senior Agency officials were alerted to the seriousness of the situation during a summer 1992 trip to the Experimental Aircraft Association's famous annual fly-in in Oshkosh, Wisconsin. Since then, general aviation technology research has become an important, if relatively small, part of NASA's new Advanced Subsonic Technology Program.

"General aviation is a latent market" compared to the construction of big jet transports, says Robert Whitehead, director of the subsonic transport division at Headquarters. This means "we have to generate interest in it, improve the infrastructure and then grow the market" before a real economic explosion can occur, he explains.

Serendipitously, recent advances in Global Positioning System (GPS) satellite-based navigation technology, small computers, expert systems and digital data links have created "the ingredients for a renaissance," according to Holmes.

The idea is to use modern computer technology to replace conventional cockpit dials and needles—derisively known as "steam gauges"—that are difficult for novice pilots to read, as well as being costly to repair and unreliable



The Beechcraft "Starship."

The CIRRUS experimental plane.

during emergencies.

Although some of this technology is already available or will be soon, NASA's expertise in human factors engineering could help to create a unified system that is much easier and cheaper to use.

GPS-related technology such as moving geographic maps and push-button flight planning is the foundation of this potential revolution. With these affordable tools, it will be "impossible to be lost" in an airplane, says Holmes.

"It will become as common to know where you are as it is to know what time it is."

"We see GPS as one of the most important pieces of technology to be implemented in our national airspace system since radar," says Richard Weiss, technical assistant to the executive director for systems operations in the Federal Aviation Administration (FAA).

Despite the problems facing U.S. general aviation today, the industry may be flying high tomorrow—with help from NASA.

Cockpit displays in the next generation of small aircraft could show engine checklists, a map of the airport, or up-to-the-minute weather conditions, along with suggested routes to avoid storm systems. A floppy disk inserted into the plane's dashboard could provide the latest information on airport supplies, or list business accommodations and tourist sites en route. A single lever would control the plane's engine, simplifying the task of flying and reducing costly engine damage from improper use.

With full application of such "touch-screen" flying technology, NASA program managers hope to reduce the time and cost to learn all-weather flying skills by 50 percent. They also aim to cut the cost of flight systems by 50 percent and trim the cost of airframe manufacturing by as much as 40 percent.

"It used to be that our customers wanted planes that flew higher, farther and faster," Holmes says. "Now they want to bring their products to market cheaper and faster."

Paul Fiduccia, executive director of the 40-member Small Aircraft Manufacturers Association (SAMA) in Washington, says that his group "views the NASA program as being essential to revitalizing U.S. general aviation."

It will give U.S. companies a "level playing field" with international competitors, Fiduccia says, while giving them incentive to spend more on internal long-range research and development.

The NASA General Aviation Technology Program will use its $2 million budget in fiscal 1994 to help refine its goals and to establish a unique government/industry/university partnership that will start developing the cockpit display technology. An estimated 79 percent of the program's projected $63 million in funding through 2001 will go directly to outside contracts.

"It's going to be very difficult to put this consortium together—the United States is just learning to do these types of things," says SAMA's Fiduccia. "NASA is the essential catalyst."

Near-term program milestones include getting the cockpit simulator on-line by early

1995, and then having an initial version flying by early 1996. Langley will manage the overall general aviation program and handle issues related to manufacturing. The Ames Research Center will lead human factors studies and training research, while the Lewis Research Center develops propulsion controls and new techniques to reduce engine noise and environmentally harmful engine emissions.

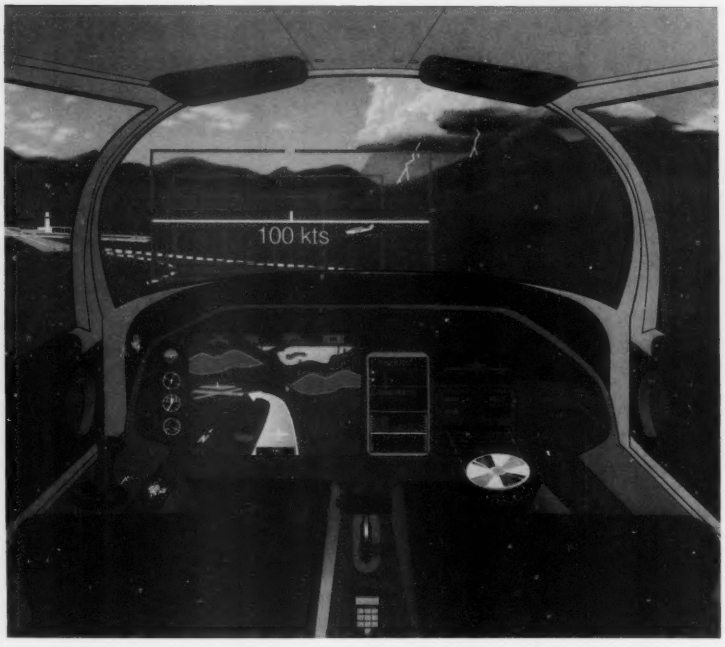
Questair's "Spirit."

Ed Stimpson, president of the 51-member General Aviation Manufacturers Association and chairman of the NASA Ad-Hoc Task Force on General Aviation, emphasizes that all of these areas must receive attention if the industry is to prosper.

Cockpit improvements "are just a small part of what the task force thinks NASA should be doing," Stimpson notes. Noise and emissions reduction, access to first-class facilities and wind tunnels, and advanced structures and materials all need to be addressed in a "highly focused" way, he says.

At the same time, he warns, "We have to be very careful not to overpromise and oversell some things in the program."

"General aviation as we knew it from the 1950s through the 1980s is in danger of disappearing."



This could be the cockpit of the future.

Beyond the potential benefits for small airplane builders, the NASA general aviation program has the potential to revitalize the informal community of industries that support them and their airports.

Although 90 percent of U.S. air traffic flies between 70 hub cities, there are 17,000 other aviation facilities in the nation, including 5,200 public-use airports, many of which are in rural areas. A successful airport can become an industrial center, with support companies and public services that produce local jobs and tax revenues. One study of small airports in Virginia found that each contributed an average of $1.6 million per year to the local economy.

Yet 43 percent of the support companies that pump gas and rent and repair aircraft at these smaller airports lost money last year. And 1.5 percent of the airports are closing down annually because of declining air traffic.

By helping industry build less expensive planes that are easier to fly, NASA could help attract new pilots and plane owners into the field.

"General aviation can play a role in this country's economic expansion," says Holmes.

"The biggest benefit of the NASA program could be to help general aviation make

the technological jump to become competitive with other modes of transportation," Fiduccia says.

While somewhere between 300,000 and 400,000 people actively fly general aviation planes, an estimated 2.5 *million* people have inactive licenses, and this group would be the first that could be attracted to more user-friendly planes.

Ken Johnson, left, is owner, builder, and pilot of the Glasair III LP (lightning protected).

Improvements to engine noise and emissions, along with the introduction of some of the new "ease-of-flying" technologies, should help the annual production of general aviation airplanes rebound from its current level of about 500 certified piston-powered planes per year to more traditional levels of 5,000 to 10,000 planes a year. A higher production rate would drive down the cost of an individual plane, and would make it more attractive for businesses to invest time and money in advanced cockpit displays that could open up aviation to a whole new group of business and pleasure flyers. It also could double manufacturing-related employment in the industry from its current level of 20,000 jobs, Holmes says.

But several ongoing challenges, including some outside of NASA's control, have the potential to slow the application of new technology to general aviation.

Current product liability regulations, which can leave a company financially responsible for accidents in planes that were built decades ago, must be loosened before big manufacturers will consider building large numbers of new piston-powered planes, Whitehead says. Legislation in this area has been proposed in Congress, but the prospects for reform are unclear.

Historically, the rigorous process required by the FAA to certify airplanes for sale also has scared off would-be innovators. But NASA and FAA officials say the situation is improving.

In an effort to cut some of the red tape, the FAA has packaged all of its major certification documents into a single publication, and has been conducting site visits and one-on-one meetings with users to help them better understand the procedures.

"We really haven't changed any of the rules," says Weiss. "We're just making it easier to get through the system."

"The biggest benefit of the NASA program could be to help general aviation make the technological jump to become competitive with other modes of transportation."

Already there are positive signs that U.S. industry is ready to participate aggressively in NASA's new technology effort. A recent NASA Small Business Innovative Research (SBIR) solicitation produced 140 aviation-related proposals, more than half of which were "highly relevant" to the new general aviation thrust, according to Holmes. The Agency hopes to fund at least 10 percent of them.

"The pent up demand [for general aviation] is there," he says.

Indeed, the proliferation of personal computers and video games has created a generation that is not afraid of relying on display technology, which bodes well for the growth of the general aviation market.

"It's going to take a while to regain the demand curve [for small airplanes]," Weiss says. "But if we prime the pump and help industry come up with the technological innovations that will make it safer to fly and will get more people interested in flying, the industry will start to grow again." •

Douglas Isbell is a special assistant for communications in the Headquarters Office of Public Affairs.

For nearly 50 years, laboratory animals have played an important role in efforts to understand how gravity influences life on Earth. Beginning with rocket tests and suborbital flights, animals also played a pioneering role in the exploration of space. In 1957, a small dog named Laika became the first true space traveler when the Soviet Union launched her into Earth orbit. Four years later, Ham and Enos made headlines as the first chimpanzees in space.

In those early days of space exploration, NASA's emphasis was on determining the possible dangers of space flight.

"When the space program began, we didn't know whether life could survive space flight," says Joan Vernikos, head of NASA's Office of Life and Biomedical Sciences and Applications. Early animal research proved conclusively that with the proper life support systems, survival in space is possible, she says.

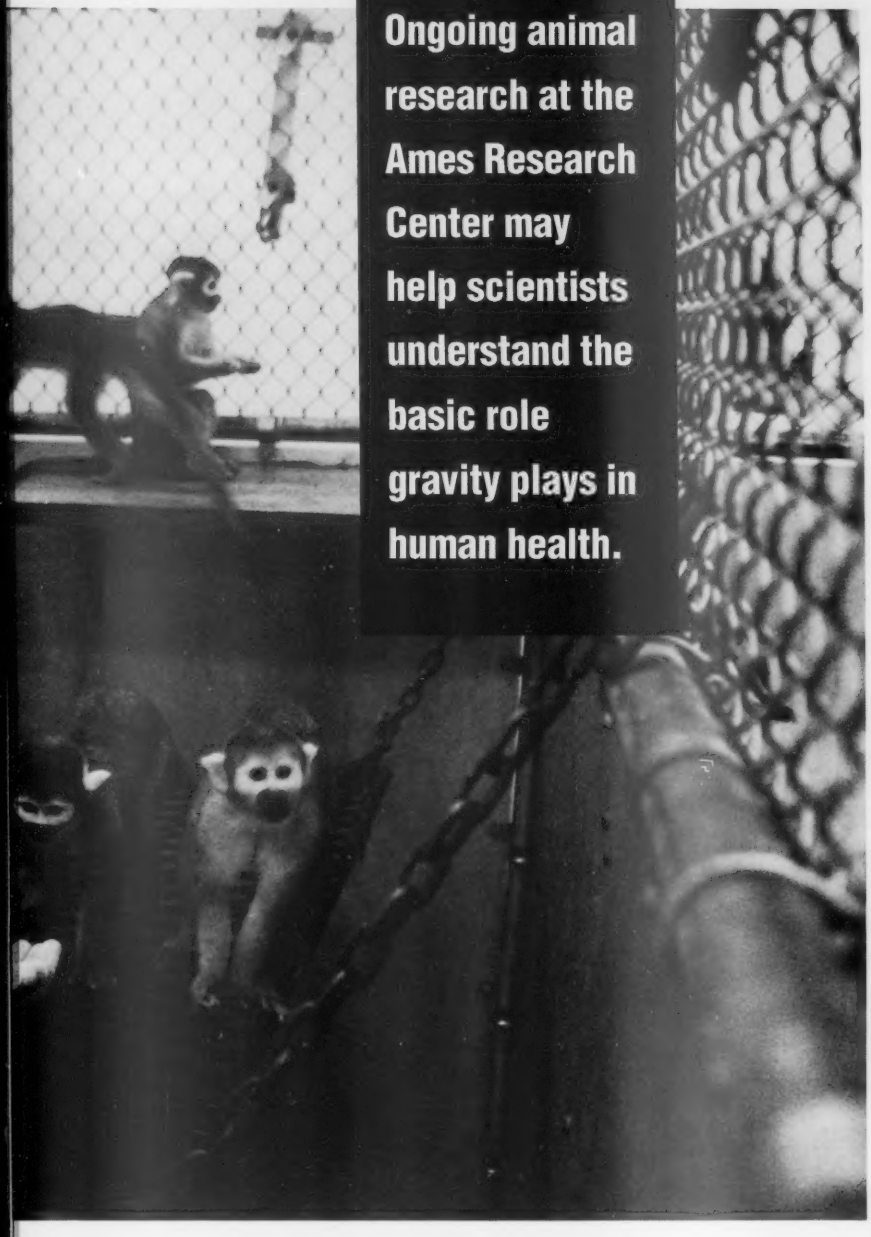
But despite more than three decades of U.S. space exploration, there have been only limited opportunities to study the effects of space flight on living systems.

"We're only beginning to develop our ability to conduct comprehensive life sciences programs in space," Vernikos says.

Until recently, technology limited the amount of information

Primate handler offers a nutritious treat to young rhesus monkeys.

A Question



Ongoing animal research at the Ames Research Center may help scientists understand the basic role gravity plays in human health.

# of Gravity

that could be gained from such experiments. Advancements in computer and other technologies now make it possible to gain a wealth of data from only a small number of subjects.

NASA scientists study animals ranging from fruit flies to monkeys in an attempt to better understand the effects of gravity—or the lack of gravity—on living beings. Vernikos says that basic research in this area helps scientists gain new perspective on fundamental biological principles. It also helps them find solutions to specific problems that affect the health and well-being of space crews, which will be particularly important as space voyages become longer. Vernikos believes this applied research ultimately could benefit people on Earth as well.

Charles Wade, chief of the Life Science Division at Ames Research Center, NASA's lead center for animal research, describes the relationship between basic and applied research as being like the parts of a pyramid.

"A lot of the work NASA is doing now provides the building blocks to the pyramid," he says. "The top of the pyramid is the solution to a problem for astronauts or for the medical community."

Gravity is such a basic force in biological development that scientists often overlook it, according to Wade.

"It shapes how we walk, how we look, how we age," he says. "The body, from the single cell to the whole animal and human, responds to gravity in various ways."

The effects of gravity become more pronounced as we age. Getting around becomes more difficult. Muscle and skin lose their tone, and day-to-day activities take more effort.

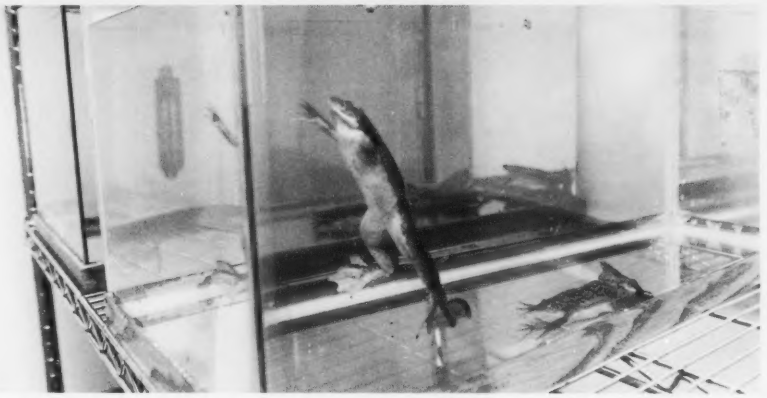
"Gravity becomes a limiting factor," Wade says. "It also becomes one of the major causes of injuries in older people."

Because both space flight and aging produce similar changes, and because those changes share a common underlying cause—a decrease in activity—studying the effects of space flight may help scientists understand the aging process.

The research involves both human subjects and laboratory animals, and sometimes these complementary studies can produce exciting results. When Ames scientists Emily Morey-Holton, Sara Arnaud and Rob Whalen shared results of their research—on both rats and humans—they gained new insights into how removing the "load" of gravitational force affects the bones of both rats and humans.

The calcium content of bone and its distribution affect how strong the bones are. Space experiments showed that production of new bone is slowed in the absence of gravity, and that there are changes in the distribution of calcium in certain bones. The total amount of calcium doesn't change much, but the changes have the potential to weaken bones after flight, says Vernikos.

"That was a very, very important finding," she says. "It showed that gravity is a strong factor in calcium deposition in bone."



South African clawed frog in aquarium at Ames. Four frogs like this one flew on the September 1992 Spacelab-J mission as part of gravitational biology research.

Further research on humans confined to bed for prolonged periods, along with Russian cosmonaut studies, have confirmed that calcium distribution within the skeleton changes even in adult humans when gravitational loads are removed.

Better care and treatment of laboratory animals has allowed NASA to reduce the number of animals required, because they are healthier.

"There is less mineral in the feet and legs and more in the skull—the same results seen in rats in one of our ground-based models," Vernikos says. "[Calcium] was not concentrated in places where it was needed to reinforce the bone against breaking," which meant that bones could be more likely to break when the subject returned to normal Earth gravity.

Further studies have shown that physical activity is a major factor influencing calcium distribution. These and related findings may eventually benefit people on Earth who suffer from bone-weakening disorders and fractures.

Studies by Muriel Ross, another Ames researcher, of the vestibular (balance) system in rats are beginning to provide insights into the functioning of balance organs. Problems with these organs contribute to motion sickness on Earth and to space motion sickness, which affects about two-thirds of all astronauts. They also are associated with Meniere's disease and with advanced age. Balance disorders often result in falls, which cause half of all deaths among the elderly, Vernikos notes.

"If the effects of space flight and hypergravity [increased gravity] on the vestibular system are anything akin to the effects on the rest of the nervous system, it means gravity plays a major role and contributes significantly to our normal level of health," Vernikos says. It also means that varying the force of gravity may some day be used as a therapeutic tool, she adds.

Ross' research has stimulated interest by the National Institutes of Health (NIH), which has signed an agreement to collaborate with NASA

on similar studies. Through other agreements, NASA makes its unique research facilities available to scientists from NIH, other federal agencies and universities throughout the country.

Most of NASA's animal research involves laboratory rats, although other species are studied when appropriate. While their systems are not identical to those of humans, rats have proven to be a good model in many respects. Rats and humans exposed to space flight show similar effects, including reduced red blood cell mass and muscle atrophy.

NASA scientists at Ames and at the Johnson Space Center also use cell cultures to test the effects of gravity.

"Cell cultures are very important, and they have their place," says Vernikos. But sometimes only live animals will do for certain investigations. Laboratory animals offer the ability to obtain tissues and perform tests not ethically possible in healthy humans. They also provide a genetic and environmental uniformity not found in humans.

NASA long ago took steps to ensure that all laboratory animals used in research would be treated properly and humanely. In addition to following all applicable federal rules and guidelines, the agency created a federal rule on the "Care and Use of Animals in the Conduct of NASA Activities." This document governs the use of vertebrate lab animals in both ground-based and space-based research. All NASA scientists, outside investigators and users of the Space Shuttle (including non-U.S. and commercial users) must comply with this rule.

"Our program exceeds all current standards," says Wade, a former chairman of the Ames animal care and use committee. All proposals for the use of animals are reviewed for scientific value by qualified, non-NASA scientists. The care and treatment of animals is further reviewed at the scientist's institution and at one or more of NASA's three animal care and use committees located at the Ames, Johnson and Kennedy centers.

NASA scientists seek to gain the maximum amount of information from each animal without jeopardizing the animal's well-being. Separate investigations are often combined in one test subject, which results in a greater scientific yield from a smaller number of animals.

Handlers wear masks and gloves to maintain a clean environment.

The Ames animal care and use committee was established several years before such committees were required by federal law. In recent years it has included a small-animal veterinarian, an attorney, a college professor and an ethicist. Two employees from local humane societies also are represented on the committee.

"We have been upfront with the outside community, and we have made no attempts to stifle interest in the program," notes Wade.

Each center's committee can approve, disapprove or require changes to proposals that involve the care and use of laboratory animals. The committees consider such questions as the appropriateness of the animal species requested, the possibility of using a non-animal alternative, the number of animals involved, and alleviation of any pain or discomfort that the animals may experience.

All NASA centers conducting animal research must also be evaluated and accredited by the American Association for the Accreditation of Laboratory Animal Care. This ensures that the highest standards in care, handling and housing of research animals are maintained.

"Our philosophy of animal care is to strive to do the best we can," says Wade. "But we can always do better—provide a better environment, take better care of the animals, get a better return from the utilization of the animals."

He notes that changes in attitudes toward laboratory animals over the past 10 or 15 years have benefitted both scientists and the animals. Better care and treatment has allowed NASA to reduce the number of animals required, because they are healthier. At the same time, improved technology has increased the amount of information that can be collected from a single test subject.

Wade emphasizes that the commitment to humane treatment of NASA's lab animals extends to all levels of the agency.

"If animals are not well taken care of and handled appropriately," he says, "you might as well throw what you're doing out the window." •

Jane Hutchison is a public affairs specialist at the Ames Research Center. Her last article for NASA Magazine, *on human bedrest studies, appeared in the Fall 1993 issue.*

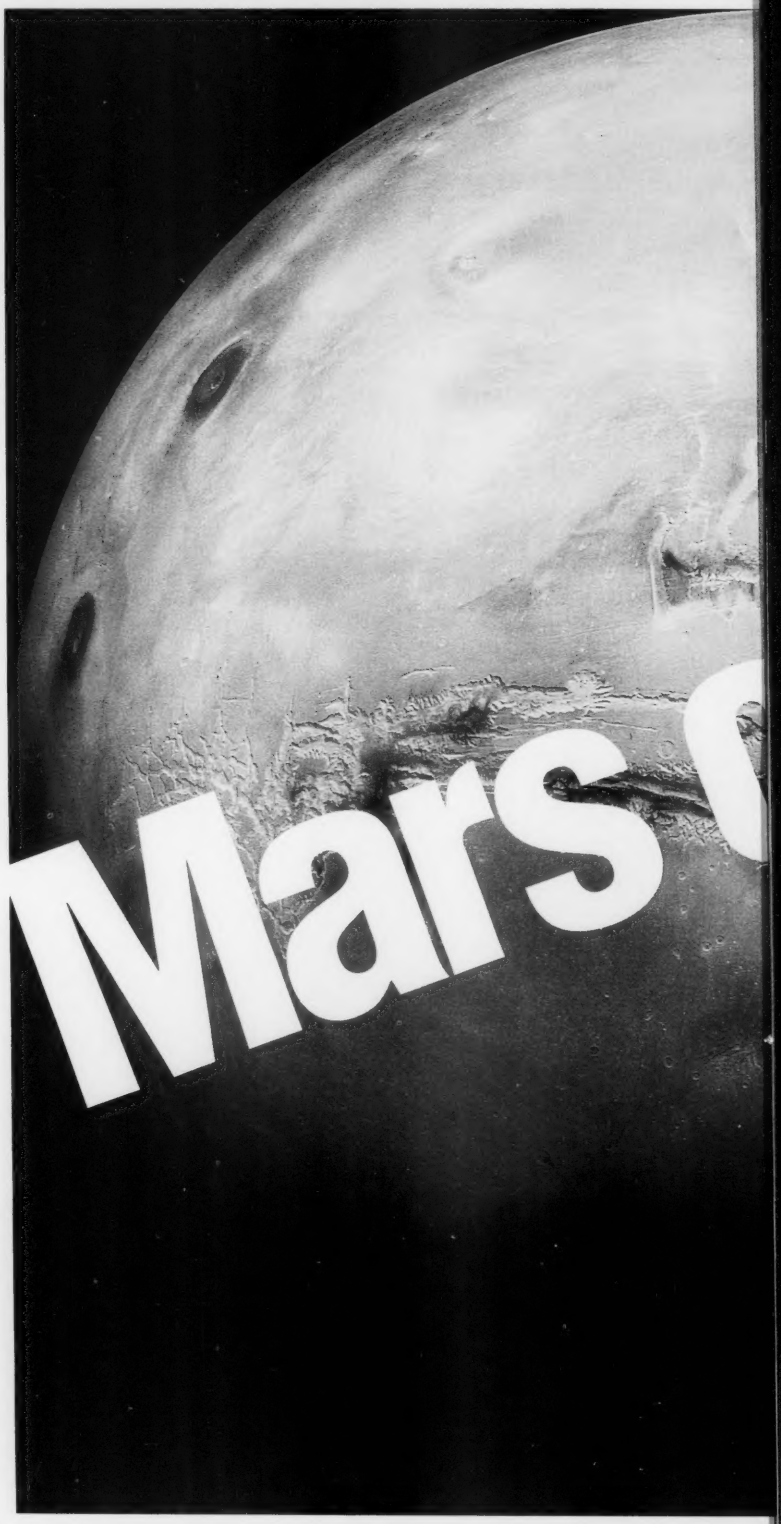
"Pink skies, towering mesas, fields of boulders, rolling sand dunes, and vast extinct volcanoes...." Sounds vaguely like some remote location in South America, but the words are not lifted from a travel brochure. They're a scientist's description of the landscape of Mars. This mysterious world, seemingly dead yet full of signs that it was once like Earth, keeps a strong grip on our imagination.

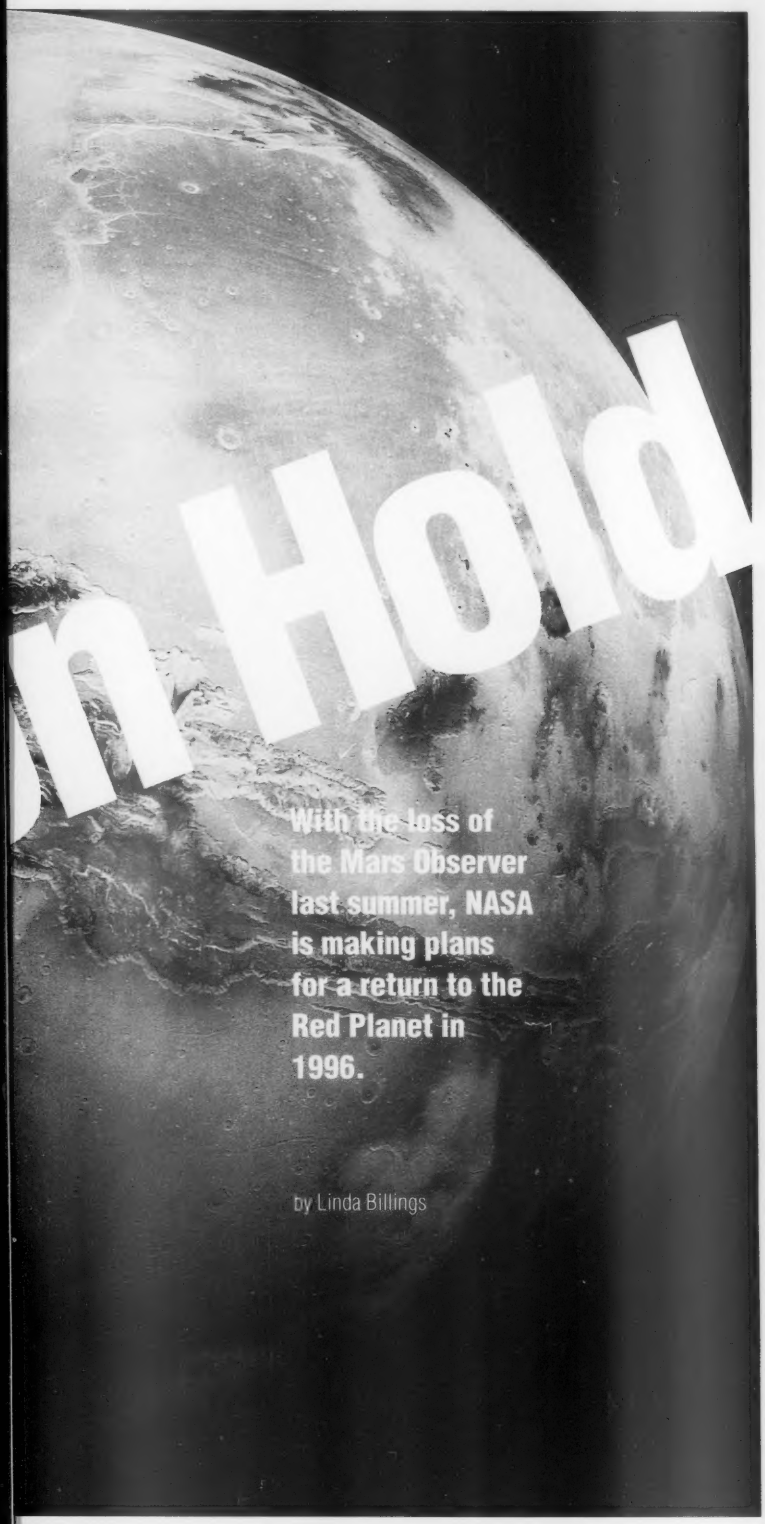
Exploration of the Red Planet suffered a setback last August 21, when NASA lost contact with its Mars Observer spacecraft just as it was reaching its destination. The most likely explanation, according to investigators from inside and outside the Agency, was that the spacecraft suffered a rupture in its propellant lines, which set the Mars Observer spinning and left it unable to contact the Earth. Attempts to re-establish communication have not been successful.

It is not, however, in the nature of space explorers to let disappointment stop them in their tracks. At the same time that NASA is adjusting to the loss of this important mission—the first launched to Mars since Viking 1 and 2 in 1975—the space community is working on plans to make up for it.

On September 1, NASA named a Mars Recovery Team to determine how the Agency might follow up on Mars Observer. Led by Jet Propulsion Laboratory Assistant Director Charles Elachi, the team included Mars Observer chief scientist Arden Albee, planetary scientist Carl Sagan, and representatives of the Jet Propulsion Laboratory, Goddard Space Flight Center, U.S. Geological Survey, Hughes Aircraft, University of Arizona, Johns Hopkins University Applied Physics Laboratory, and the Defense Department's Ballistic Missile Defense Office.

On October 1, NASA Administrator Daniel S. Goldin decided that NASA would forego a make-up mission to Mars in 1994, and would begin planning instead for a launch during the next favorable "window" in November 1996. The options include re-





nHold

With the loss of the Mars Observer last summer, NASA is making plans for a return to the Red Planet in 1996.

by Linda Billings

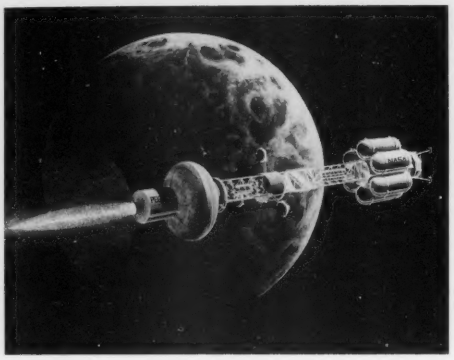
flying a second Mars Observer mission or breaking up the science payload into two or more smaller flights. As Wesley Huntress, Associate Administrator for Space Science, said at the time of the failure investigation committee's report, "We will find a way to go back to Mars."

Throughout the global space community, plans for exploring Mars are moving along as well. In October, NASA took part in the first meeting of a new International Mars Exploration Working Group (IMEWG), which included space officials from Austria, Canada, France, Germany, Great Britain, Italy, Japan, Russia, the United States and the European Space Agency. Wes Huntress was responsible for organizing the group and chairing the first meeting, which took place in Austria during the 1993 congress of the International Astronautical Federation.

Each participating agency sent three representatives—one scientist, one engineer and one administrator. According to NASA delegate Joe Boyce of the Solar System Exploration Division, the IMEWG is chartered to coordinate Mars exploration mission planning, plot a strategy for Mars exploration and plan an international Mars network mission. IMEWG subgroups already are at work on the network mission plan and exploration strategy.

Even though the timeline for Mars mission planning is decades long, important preparatory work is now under way throughout NASA. For the foreseeable future, the Agency's Solar System exploration activities will be robotic. Through robotic exploration, the space community will be able to answer critical questions about the places we want to explore (primarily but not exclusively Mars), as well as the technologies required for long-duration missions and the human capacity to live and work in space.

In 1993, NASA's Office of Exploration, which is responsible for planning human missions to the Moon and Mars, received no funding from Congress. As a result, it merged with the Office of Space Science,



A Cargo Vehicle Propulsion element could support outer planet robotic exploration missions.

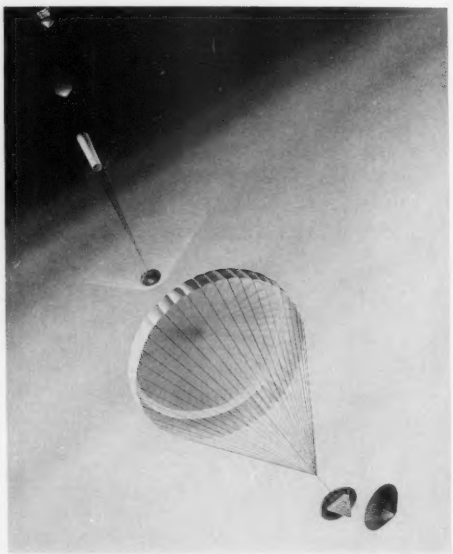
and was renamed the Mission From Planet Earth Study Office, with a handful of people on staff.

In a letter addressing the closing of the Office of Exploration, Administrator Goldin made it clear that this organizational change does not reflect any faltering in NASA's commitment to long-range exploration goals. Citing "the inevitability of sustained human exploration of the Solar System," Goldin wrote, "I firmly believe there is no lack of desire in the vast majority of our fellow citizens to begin this journey. But we all know that events of the past several years have combined to force the nation to focus attention on more immediate problems facing America. That is not to say we will not, and must not, look to the future....I believe that deep down, whatever our professional calling, there is an unshakable faith and hope that the human race will establish itself in places beyond our home planet."

Above, right and in photos below, are artist's conceptions of the Mars Environmental Survey (MESUR) Pathfinder approaching and landing on Mars.

The Mars Environmental Survey (MESUR) Pathfinder mission, to be launched in 1996, is next up on NASA's Mars manifest (see page 29). Whatever kind of recovery mission NASA pursues, it will be compatible with MESUR Pathfinder, the first mission planned under the Discovery program of small-scale, low-cost planetary spacecraft.

MESUR Pathfinder will place a lander and small robotic rover on the surface of Mars in 1997. This mission is designed as a precursor to a full-scale MESUR mission, which will place a network of small-scale, automated research stations on the surface



of Mars to collect data on weather, climate, surface chemistry and geology. MESUR Pathfinder also will test atmospheric entry, descent and landing systems to be flown on the MESUR mission.

Meanwhile, even though researchers are disappointed by the loss of the Mars Observer, the scientific study of Mars has not come to a standstill. The archive of data collected by the Viking orbiters/landers from 1976 to 1981 is still an invaluable resource. As planetary scientists wait for newer, better information, they continue to extract new information from Viking's yield, using increasingly sophisticated data processing techniques coupled with plain old brain power.

Analysis of Viking imagery in the 1970s showed that Mars once had large bodies of standing water—lakes or oceans—on its surface, as well as rivers and streams of flowing water. Further analysis has revealed what appear to be the martian equivalent of islands, sandbars and shorelines. But scientists need higher-resolution pictures to prove definitively that these features are, indeed, what they think they are.

While the Viking data have contributed immensely to our understanding of Mars, they also have provided fuel for many disputes. With all that we have learned about the planet in just three decades, we still understand very little about its history and nature: How exactly did the surface features of Mars evolve? When did volcanic activity cease, and why? Where did the water go? Did life ever exist there? Researchers need more detailed information on daily and seasonal weather patterns, geological features, the migration of water vapor over a complete martian year, and many other factors to answer these and other questions.

With the MESUR missions scheduled to extend into the next century, plans for robotic exploration of Mars, let alone human missions, seem to be stretching very far into the future. It's important to note, however, that slow but steady progress has been the hallmark of Mars exploration since its beginnings. And in these tight budgetary times, slow and steady is the only reasonable way to go. •

Linda Billings last wrote for NASA Magazine *on the TOPEX-POSEIDON satellite in the summer 1993 issue.*

MESUR Pathfinder: Roving the Martian Surface

The Mars Environmental Survey (MESUR) Pathfinder will be launched in November or December 1996 onboard a Delta rocket. The single spacecraft will cruise directly to Mars, enter the atmosphere with a Viking-derived heat shield and land with the aid of parachutes, rockets and airbags. Landing is scheduled for July 1997.

After impact on the surface of Mars, the lander will transmit the engineering and science data collected during its descent through Mars' thin atmosphere. Then its camera will take a panoramic image of its surroundings and begin transmitting it directly to Earth at a few hundred bits per second.

The 10-kilogram rover, which will have been carried in a stowed configuration, will extend to its full height of 280 millimeters (11 inches) before it leaves the lander. Once on the surface, the rover will be controlled by an Earth-based operator.

This Micro-rover Flight Experiment, or MFEX, will conduct a number of technology experiments, including tests of its imaging and communication systems as well as its ability to characterize the martian soil and rocks.

The rover's main science objectives are to deploy an alpha-proton-X-ray spectrometer (APXS) and take close- up images of martian features. The rover will place the APXS against a rock, collect a spectrum to determine the rock's composition and transmit that spectrum to the lander for return to Earth. The APXS also may measure soil types.

In addition, the rover will make a black-and-white image of any rock on which the APXS is used and transmit the image to the lander for return to Earth. The rover computer is capable of compressing and storing a single image on-board.

Because MESUR Pathfinder is primarily an engineering demonstration, assessment of the lander's condition is very important. The rover will image the lander at least once to assess its condition after landing. The mission could be revised to permit the rover to take close-up images, possibly in stereo, of any damaged areas of the lander.

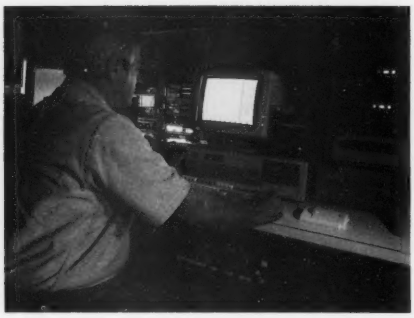
Because of cost constraints, both the lander and rover have limited redundancy. Also, the Martian environment is harsh, with temperatures averaging about 0 to -100 C (32 to -148 F) daily. Therefore, the surface mission is designed to achieve its primary objectives in a relatively short time. The most important objectives are planned for the first three Martian days (called sols, which last 24.6 hours). By the end of the seventh or eighth day of operations, many lander images will have been transmitted and the primary rover experiments accomplished.

The prime mission is envisioned to be accomplished within 10 meters of the lander to take advantage of the highest resolution lander images. For an extended mission following that period, the rover can be risked on longer trips away from the lander, and may even go over the horizon and out of range of the lander's camera by using its own camera for navigation. •

Langley

Live From Columbia

Last October's STS-58 mission marked a first for the Langley Research Center—the first time the center had ever



received a live feed of data from the Space Shuttle. One of the many experiments onboard Columbia during its 14 days in space was Langley's Orbital Acceleration Research Experiment (OARE), which measures drag on the vehicle in orbit and during the early stages of reentry. The STS-58 measurements are being used to establish models of orbital aerodynamic behavior. In the picture above, Langley electronics engineer and OARE instrument manager Herb Kowitz evaluates the live data received during the flight. The OARE sensor is capable of discerning accelerations as small as one-billionth of the normal gravitational acceleration at the Earth's surface. OARE will be adapted to support microgravity work and will fly again next year on STS-62 and STS-65. •

Kennedy

Economic Power

The Kennedy Space Center is spending less on electricity and getting paid for it, to boot. Last October, the Florida Power & Light Company (FPL) presented center Director Robert Crippen with a $220,000 rebate for Kennedy's ongoing efforts to reduce its energy consumption and costs. Crippen, who called the letter from FPL informing him of the rebate "the best piece of mail I've ever received from the power company," also pledged to continue looking for further ways to operate the center more efficiently. The rebate was the largest FPL has ever awarded to a Central Florida customer. In case you're wondering, half of the rebate was deposited in the U.S. Treasury, while NASA retained the other half for use in additional energy-saving initiatives. •

Ames-Dryden

Flying with Fibers

The Dryden Flight Research Facility's F/A-18 Systems Research Aircraft took to the air last October to test a fiber optic control system that could result in lighter, more fuel-efficient airplanes with more capable control and monitoring systems. The fiber optic systems—small bundles of light-transmitting cables—weigh less and take up less space than the copper wiring in today's aircraft. The system is less affected by radio signals and lightning than other control systems, is free from short-circuit arcing, and can carry more electronic signals. Dryden and the Lewis Research Center have been working with the U.S. Navy since 1985 on fiber optic control system integration. •

Ames-Moffett Field

Off to the Races

A small group of Ames employees pitched a pair of cheery yellow and white striped tents and set up a variety of aeronautical exhibits last September at the 30th annual National Championship Air Races in Reno, Nevada. Although the center has staffed similar exhibit booths at other air shows, this was the first time at this particular show.

"We wanted to emphasize that the first "A" in NASA stands for aeronautics," says Ames' acting chief of external affairs, Michael Marlaire.

Included among the exhibits were models of the National Aero-Space Plane, the Stratospheric Observatory for Infrared Astronomy (SOFIA) and exhibit panels depicting such advances as Short Takeoff/Vertical Landing aircraft, dual-use technologies and high performance computing. Michael Mewhinney of the Ames Media Services Office says the air show drew thousands of enthusiastic spectators to the scenic desert site to watch the air races, air balloon racing, sailplaning and parachute jumping. •

Under desert skies at the 30th annual National Championship Air Races in Reno.

JPL

The Glass Gumshoe

Scientists at the Jet Propulsion Laboratory have turned a type of glass used as a sensor for studying planetary atmospheres into a detector that could be important in monitoring atmospheric pollutants on Earth. The metal-containing silica gel glass is hard and transparent like regular window glass, but is highly porous. Vanadium metal in the porous channels turns the glass into a kind of pollution "detective." When atmospheric gas molecules seep into the channels, they attach to the metal and cause its color to change. Two important pollutants, hydrogen sulfide and nitrous oxide, turn the glass deep amber and lemon yellow, respectively, while formic acid turns it a dark green. JPL's Albert Stiegman says that the unusual property of the glass would "recommend [it] as a new and potentially important type of environmental chemical sensing element." •

Stennis

Teamwork

Stennis Space Center has embarked on its first joint venture in technology transfer with Mississippi's only medical research center. Stennis and other NASA centers are collaborating with doctors from the University of Mississippi Medical Center in Jackson to see if space-developed imaging technology can provide three-dimensional views of bone fractures as well as more detailed looks at stomach ulcers. Rick Galle, Stennis' technology transfer officer, invited the doctors to submit a list of medical problems that NASA might then match to existing technologies.

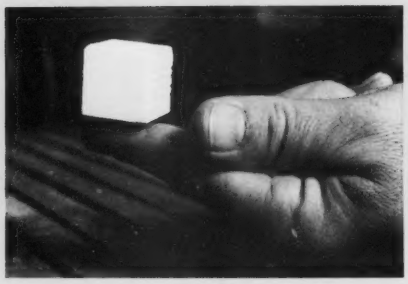
"We don't always know the ways in which what we've developed can be used in medicine, and researchers aren't always familiar with the technology that's available to help them solve their problems," he says. "The association that has developed between the two institutions should make the sharing of information much easier." •

Johnson

Oso Wonderful

Johnson's Maintenance, Mechanical and Logistics Section is "bearing" up quite well now that it has a new mascot—a spectacled bear cub named "Oso" that makes its home in the Houston Zoo. The name, which means "bear" in Spanish, happens coincidentally to be the call sign for the office's Operations Support Officer (OSO) in the international space station's Control Center Complex, which will have responsibility for in-orbit maintenance, structures and operation of mechanisms.

The spectacled bear typically lives in the rain forest, and is the only bear species native to South America. Oso came to Houston as part of the Species Survival Program, which promotes cooperative breeding of at-risk animals among U.S. zoos. Only about 200 spectacled bears currently live in the United States. The OSO staff will sponsor Oso during his expected two-year stay in Houston. •



Sometimes you find spinoffs in the most unlikely places—underneath the Space Shuttle, for example. Scientists are now exploring the use of the Shuttle's ceramic insulation as a substitute for bone material. The work could provide an alternative to using human bone for implants.

Body by Shuttle

by Jane Hutchison

The same material that keeps the Space Shuttle from burning up when it re-enters the Earth's atmosphere may someday soon help rebuild ailing bodies.

A NASA-industry team has begun studies to determine whether Reusable Surface Insulation (RSI), a composite of silica-alumina fiber and borosilicate glass, can be used as an implant for skeletal reconstruction. The team includes researchers at the Ames Research Center and engineers and physicians from BioMedical Enterprises Inc. (BME) and the University of Texas Health Science Center, both in San Antonio.

If their work succeeds, says Casey Fox, a biomedical engineer at BME, "The contribution to the relief of human suffering is potentially enormous."

RSI has several properties that make it ideal for bone implants. In addition to being biocompatible, it provides a porous framework that allows infiltration by normal bone cells and deposition of bone mineral. The result could be complete integration of the implant into normal bone.

Howard Goldstein, senior staff scientist in Ames' Thermosciences Division, is cautiously optimistic about using the material for this new purpose.

"We're still a long way from having a bone implant that's ready for human use," he says. "But we have data that show the tile material has excellent promise for use as a bone implant."

Goldstein says Ames engineers must first improve the material properties of the ceramic fiber composite. They also will have to increase the pore size of the material for use as a bone scaffolding, while increasing its strength and maintaining biocompatibility.

Physicians perform between 1.2 million and 1.7 million orthopedic and dental procedures each year that could benefit from the availability of the artificial bone implant material, Fox says.

"People with bone disorders resulting from trauma, disease and degenerative skeletal changes associated with aging are likely to benefit from successful development of this bone implant," he says.

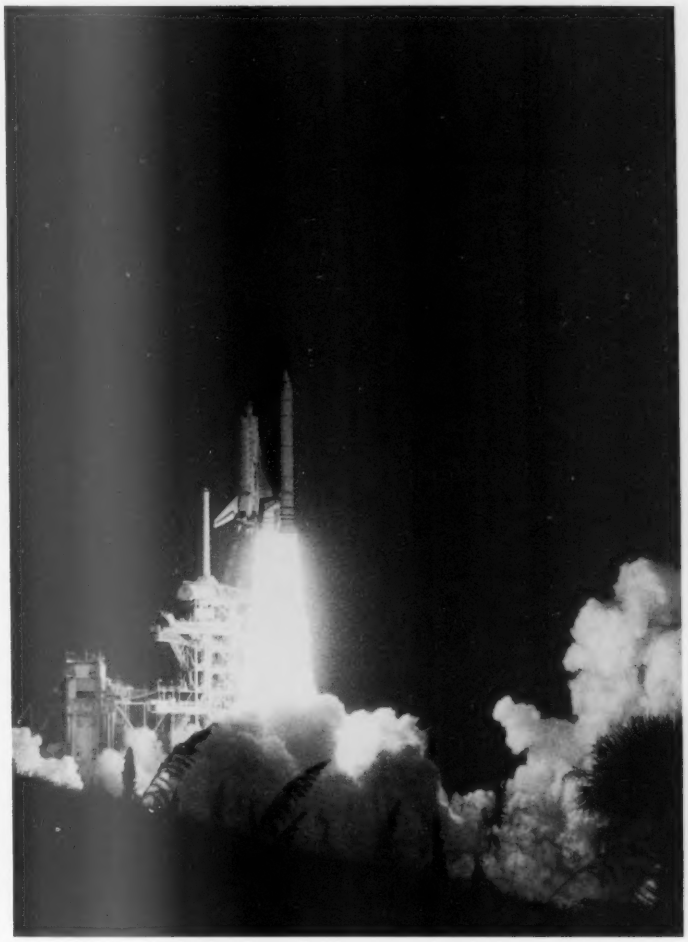
Fox expects the new bone implant to be used with traditional implants such as metal pins, wires, plates and screws when treating a fracture. The porosity and surface chemistry of the ceramic material may allow administration of medicines that promote bone healing. Physicians also may use the artificial material instead of bone transplanted from humans, thereby preventing disease transmission.

Tests by Fox and Thomas Aufdemorte of the University of Texas Health Science Center already have shown that RSI materials are biocompatible and potentially useful for oral and general skeletal trauma and reconstructive treatment. Now the team will have to determine the safety and efficiency of their use as bone implants. After developing the product further in the laboratory, Fox and Aufdemorte may test it in experiments onboard the Space Shuttle. Finally, they would have to get approval from the U.S. Food and Drug Administration (FDA) to use the ceramic in humans. Fox expects the development, testing and market approval process to take about six years.

This is an excellent example of how innovative technology developed by the space program can be applied to broader societal problems, says Geoff Lee, Ames' technology transfer officer. In addition to its potential medical benefits, the project may produce economic and educational benefits as well, including the establishment of a regional medical device manufacturing facility in rural southern Texas. It also may support medical device manufacturing engineering education at two minority universities near the Texas-Mexico border. •

LAUNCHES

- STS-62 launch
  — USMP-2/OAST-2
- STS-59 launch
  — SRL-01
- STS-65 launch
  — IML-01



EVENTS

20
JULY
25th anniversary of Apollo 11.

National
Aeronautics and
Space
Administration

U·M·I

THIS PUBLICATION CEASED WITH WINTER 1994.